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㉒ Polymer claddings for optical fibre waveguides.

㉓ An optical fibre comprising a core coated with a cladding composition having a lower refractive index than the core, said cladding composition comprising a fluorinated mono-acrylate, a polyfunctional cross-linking acrylate being difunctional or higher, and a photoinitiator, said cladding composition comprising less than 0.3% by weight of a mono- or polyfunctional thiol and being cured or cross-linked.

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Description

POLYMER CLADDINGS FOR OPTICAL FIBRE WAVEGUIDES

This invention relates to optical fibres and in particular to optical fibres comprising a glass core coated with a polymer cladding.

5 The use of optical fibres as a means of transmitting data has received widespread interest. Information transfer using a modulated light beam guided by a glass or plastics fibre has been utilized in many applications including telecommunications and computer link-up and data base use. Advantages of the use of fibre optic linkages are very high information carrying capacity compared to metal wires carrying electrical signals and freedom from external interference.

10 Optical fibres comprise a core, generally an inorganic glass such as fused silica or a synthetic resin, and a cladding of a material having a lower refractive index than the core, which cladding confines the light energy to propagate in the core by total internal reflection. The refractive index of fused silica is 1.458 at room temperature and there is a limited range of materials which have refractive indices below this value. The efficiency of propagation increases as the difference in refractive index between the core and the cladding should be at least 0.03 units less than that of the core, preferably at least 0.05 units less.

15 Prior art cladding materials include thermoplastic polymers which are coated on the optical fibre by melt extrusion through a dye. This method of cladding suffers from the disadvantages that it is difficult to obtain thin coatings and the coatings tend to be loosely bonded to the silica core. Other polymers have been applied by solvent coating. However, solvent coating has the disadvantages that it may be necessary to coat a fibre several times until the desired thickness is obtained and the necessity of handling high solids solutions with attendant problems of bubbling of the coating. Furthermore, there is the additional problem of pollution of the environment during evaporation of the solvent.

20 Cross-linkable polymeric coating compositions have been employed which are rapidly cured after coating by heating or exposure to ultra violet light. Examples of such compositions are disclosed in United States Patent Nos. 4099837, 4125644 and 4511209.

25 British Patent No. 1262526 discloses an optical element e.g. a lens, view aperture etc. comprising a solid transparent base e.g. a thermoplastics material, on which is coated a fluorine-containing transparent, thermoset organic polymer having an index of refraction within 0.02 units of the base. The polymer is formed from a fluorine-free acrylic monomer and a fluorine-containing acrylic monomer, at least one of which monomers being polyfunctional. The specific coating compositions disclosed utilise at least 70% by weight of the fluorine free acrylic monomer.

30 United States Patent No. 4511209 discloses a cladding composition for plastic clad silica optical fibres comprising:

35 a highly fluorinated monofunctional acrylate with a refractive index below 1.38 and constituting more than 50% by weight of the composition,
a polyfunctional acrylate being trifunctional or higher serving as a cross-linking agent,
a mono- or polyfunctional thiol that functions as a synergist preferably a thiol containing silane e.g. gamma-mercaptopropyl trimethoxy silane, and
a photoinitiator.

40 The cladding compositions are dip or spray coated onto the fibre and exposed to ultra violet radiation to cure the coating. The hard clad optical fibres produced have attenuation often below 10 dB/km and exhibit superior temperature behaviour than silicone clad optical fibres.

The present invention provides alternative cladding formulations for optical fibres.

45 Therefore, according to the present invention there is provided an optical fibre comprising a core coated with a cladding having a lower refractive index than the core, the cladding composition comprising a fluorinated monoacrylate, a polyfunctional cross-linking acrylate being difunctional or higher, and a photoinitiator, the composition comprising less than 0.3% by weight of a mono- or polyfunctional thiol and being cured or cross-linked.

50 Also according to the invention there is provided a cladding composition for optical fibres comprising from 40 to 95% by weight of a fluorinated acrylate, from 2 to 35% by weight of a polyfunctional cross-linking acrylate being difunctional or higher and from 0.5 to 20% by weight of a photoinitiator, the composition comprising less than 0.3% by weight of a mono- or polyfunctional thiol.

55 The cladding composition of the invention may readily be applied by dip coating and can be immediately photopolymerised to cause curing or cross-linking, by exposure to ultra violet light to provide optical fibres having equivalent and often superior properties to those of the prior art. In particular the adhesion to glass of the cladding composition of the invention is superior to that of the composition of United States Patent No. 4511209. If the formulations of the invention additionally comprise other vinyl functionalized components e.g. (meth)acrylic silanes and (meth)acrylic acid the adhesion to glass is further increased.

60 The cladding compositions of the invention differ from the compositions of United States Patent No. 4511209 in that they do not require the presence of a thiol synergist. The function of the synergist is not defined although suitable compounds are identified as being of the gamma-mercaptopropyl trimethoxy silane type. The most likely function of these compounds is to chain transfer the polymer chain to the mercapto function and then via the silane, bond the polymer to the core surface. This results in the polymer matrix having

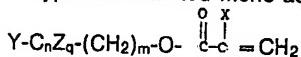
silane groups appended only at the termini of the polymer chains. In the composition of the present invention when adhesion enhancers, e.g. acrylic silanes, are employed it results in the incorporation of the adhesion enhancer through the matrix thereby significantly promoting adhesion.

The fluorinated mono-acrylates used in the compositions of the invention possess one polymerisable vinyl group. The term acrylate is used in the generic sense and includes not only derivatives or acrylic acid, but also methacrylic and other modified acrylic acids.

The fluorinated mono-acrylates possess a fluoro aliphatic group in which the higher of a minimum of three C-F bonds are present or 25% of the C-H bonds have been replaced by C-F bonds.

The fluoroaliphatic radical is generally a fluorinated, preferably saturated, monovalent, non-aromatic, aliphatic radical of at least two carbon atoms. The chain may be straight, branched, or, if sufficiently large, cyclic, and may be interrupted by oxygen atoms or nitrogen atoms bonded only to carbon atoms. A fully fluorinated group is preferred, but hydrogen or chlorine atoms may be present as substituents in the fluorinated aliphatic radical; generally not more than one atom of either is present in the radical for every two carbon atoms. Preferably the radical contains a terminal perfluoromethyl group. Preferably, the fluorinated aliphatic radical contains not more than 20 carbon atoms. More preferably the fluorinated aliphatic radical is cycloaliphatic, such as perfluorohexyl or perfluoropentyl. The presence of a fluorinated cycloaliphatic radical provides the unobvious advantage of a tougher cured coating composition in which thermal oxidative degradation processes are retarded compared to acyclic compositions. It is then possible to extend the use of the cladded fibre to a broader temperature operating range without sacrificing the optical clarity and colourlessness of the coating.

Typical fluorinated mono-acrylates used in the invention are of the general formula:



In which:

Y represents H, F or Cl;

Z represents H, F or Cl;

X represents H or an alkyl group, preferably CH₃,

n is an integer from 2 to 12,

q is an integer from 4 to 24,

m is 0, 1 or 2,

with the proviso that for Z not more than one atom of hydrogen or chlorine is present for every two carbon atoms in the group C_nZ_q.

Specific examples of such compounds include:

1,1-dihydroperfluorocyclohexane carbinol acrylate,

1,1-dihydroperfluorocyclohexane carbinol methacrylate,

1,1-dihydroperfluorocyclopentane carbinol acrylate,

1,1-dihydroperfluorocyclopentane carbinol methacrylate,

1,1-dihydroperfluoro-octyl acrylate,

1,1-dihydroperfluoro-octyl methacrylate,

1,1-dihydroperfluoro-butyl acrylate,

1H,1H,5H-octafluoro-pentyl acrylate,

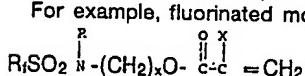
1H,1H,11H-eicosfluoro-undecyl acrylate,

Hexafluoro-isopropyl acrylate,

Perfluoropentyl acrylate.

The acrylates may also possess other atoms e.g. sulphur and nitrogen, outside the fluoroaliphatic radical.

For example, fluorinated monoacrylates of the following general formula may be employed:



In which:

X is as defined above,

R' represent a fluoro aliphatic radical, preferably C_yF_{2y+1} in which y is an integer from 3 to 12,

R' represents an alkyl group, generally of 1 to 5 carbon atoms, and

x is 1 or 2.

Specific examples of such compounds include:

2-(N-ethyl perfluoro octane sulphonamido)ethyl acrylate,

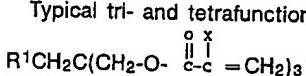
2-(N-ethyl perfluoro octane sulphonamido)ethyl methacrylate,

2-(N-butyl perfluoro octane sulphonamido)ethyl acrylate.

Mixtures of two or more fluorinated mono-acrylates may also be employed.

The poly-functional cross-linking acrylates used in the invention are at least difunctional, preferably trifunctional or higher. The compounds generally have a molecular weight of less than 600.

Typical tri- and tetrafunctional acrylates have the general formula:



in which:

X is as defined above, and

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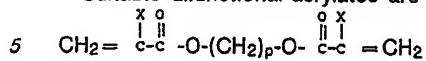
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R¹ represents an alkyl group, generally of 1 to 5 carbon atoms (e.g. methyl), hydroxy, or -O.COC(X)CH₂ in which X is as defined above.

Suitable difunctional acrylates are of the general formula:



in which:

each X is as defined above and
p is an integer from 3 to 8.

Examples of cross-linking acrylates include:

- 10 Trimethylol propane tri(meth)acrylate,
1,4 butanediol di(meth)acrylate,
1,3 butanediol di(meth)acrylate,
1,6 hexanediol di(meth)acrylate,
Pentaerythritol tetra(meth)acrylate,
15 Pentaerythritol tri(meth)acrylate,
Dipentaerythritol penta(meth)acrylate, and
Hydantoin hexa acrylate.

Mixtures of cross-linking acrylates may be employed.

The photoinitiator may comprise any of the photoinitiators known in the art e.g. d-hydroxyacetophenone type photoinitiators. Examples of photoinitiators are those commercially available from Ciba Geigy under the Trade Marks Irgacure 651, Irgacure 500, Irgacure 184, and those commercially available from Merck under the trade names Darocur 1173 (2-hydroxy 2-methyl 1-phenyl-1-propanone) and Darocur 1116 (2-hydroxy-2-methyl-1-(4-isopropylphenyl)-1 propanone).

In general suitable cladding compositions will have the following formulation:

25	fluorinated mono-acrylate	50 to 95% by weight
	cross-linking acrylate	2 to 35% by weight
30	photoinitiator	0.5 to 20% by weight.

Preferably the components are selected within the following ranges:

35	fluorinated mono-acrylate	75 to 95% by weight
	cross-linking acrylate	2 to 10% by weight
	photoinitiator	0.5 to 10% by weight.

40 In addition to the three components the compositions preferably include an adhesion enhancer e.g. a compound having a vinyl functionality and being different from the fluorinated mono-acrylate and the cross-linking acrylate. The adhesion enhancers possess a single polymerisable vinyl group, and may be methacrylate, preferably acrylate silanes such as 3-tri(m)ethoxy-silylpropyl(meth)acrylate. Alternatively acrylic or methacrylic acid may be used as an adhesion enhancer.

45 The adhesion enhancers generally increase the bonding strength of the cladding composition to the silica by at least 10%, generally at least 20% compared with cladding compositions in which the adhesion enhancers are absent. Generally, the adhesion improves as the concentration of adhesion enhancer is increased. However, the refractive index of the cladding material also rises as the proportion of non-fluorinated material is increased, which is undesirable. Thus a compromise must be made, and best results have been obtained with the adhesion enhancer present in the range 1 to 25%, preferably 2 to 15% by weight of the composition.

55 The cladding compositions may also comprise a thermal stabilizer/antioxidant. Low loss optical fibres must pass a stringent cold/hot temperature cycling test. The optical fibres are kept at -65°C for four hours and monitored as a function of loss in dB/Km. The fibres are then brought back to room temperature for two hours and thereafter held at +125°C for four hours. Again the temperature is brought to ambient for two hours and the loss of the optical fibre is recorded. It has been found that the presence of up to 5%, generally 0.001% to 5%, preferably 0.01 to 1% by weight of one or more thermal stabilizers/antioxidants compatible with the cladding composition provides improved stability to the cold/hot cycling test. Suitable stabilizers/antioxidants include low melting hindered phenols and thioesters. Specific examples include 2, 6-di-tert-butyl-4-methyl phenol commercially available under the trade name Ultranox 226, octadecyl - 3,5-di-tert-butyl-4-hydroxyhydrocinnamate commercially available under the trade name Irganox 1076, 2,6-di-tert-butyl-4-sec-butyl phenol commercially available under the trade names Isonox 132 or Vanox 1320, and dilauryl thiodipropionate commercially available under the trade name Cyanox LTDP. A combination of thioester and hindered phenol has proved to be particularly effective.

65 The core of the optical fibres of the invention is preferably formed of an inorganic glass, more preferably

fused silica, but may optionally be formed of a synthetic resin. The cladding composition is selected to provide a refractive index lower than that of the core, preferably at least 0.03 units less, more preferably at least 0.05 units less than the refractive index of the core.

The optical fibres of the present invention may be prepared by conventional techniques employing the cladding compositions of the invention.

The optical fibres of the invention may also possess a protective layer such as those known in the art. For example a protective coating of a fluoropolymer e.g. poly (tetrafluoroethylene), may be coated as an extrusion by passing the clad fibre through a melt of the fluoropolymer. A suitable fluoropolymer is commercially available from Dupont under the trade name Tefzel 210.

The accompanying drawing illustrates suitable apparatus for preparing a coated optical fibre in accordance with the invention.

A glass fibre 2 is drawn from a pure glass preform 4 held in a furnace 6 on a standard glass drawing tower. The tower is provided with a coating station comprising a coating cup 8 containing the cladding composition and the metering die 10. The coated fibre is passed immediately through an ultra violet curing station where it is photopolymerised and cooled on a take-up spool 14. A typical fibre will have an overall diameter of 200 microns and a cladding thickness of 10 microns.

The Invention will now be illustrated by the following Examples.

In the Examples the following components were employed:

Mono-acrylate A:	2-(N-ethyl perfluoro-octane sulphonamido)ethyl acrylate commercially available from Minnesota Mining and Manufacturing Co., purified by extraction with ethanol.	20
Mono-acrylate B:	1,1-dihydroperfluoro- octylacrylate (commercially available from Minnesota Mining & Manufacturing Co.)	25
TMPTMA:	trimethylopropane trimethacrylate	30
HHA:	hydantoin hexa-acrylate (commercially available from Minnesota Mining & Manufacturing Co.)	35
HDDA:	hexanediol diacrylate	40
acrylate silane:	3-trimethoxysilylpropyl methacrylate	
IG651:	Irgacure 651 commercially available from Ciba Geigy (benzildimethylketal)	45
IG500:	Irgacure 500 commercially available from Ciba Geigy	
IG184:	Irgacure 184 commercially available from Ciba Geigy	50
thiol synergist:	gamma-mercaptopro- pyl trimethoxsilane	55

EXAMPLE 1

A cladding composition was prepared by mixing the following components:

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Mono-acrylate A	92 parts by weight
TMPTMA	4 parts by weight
IG651	4 parts by weight

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Coated fibres were prepared by the technique described with reference to Figure 1 to produce coated fused silica optical fibres having an overall diameter of 200 micrometres and a cladding thickness of 10 micrometres.

10 The coated fibre was tested using a Photon Kinetics spectrophotometer and an attenuation figure of 4.8 dB/Km at 812 nm was recorded. Commercially available optical fibres in accordance with United States Patent No. 4511209 were tested under identical conditions and recorded an attenuation figure of 6.2 dB/Km.

EXAMPLES 2 TO 9

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Comparison with fibres of US Patent No. 4511209

The formulations reported in Table 1 were prepared.

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Table 1

(parts by weight)

Example	Mono-acrylate A	Mono-acrylate B	TMPTMA	IG651	thiol silane	acrylic acid	acrylate silane
25	2	944	-	44	54	-	-
	3	890	-	44	54	60	-
	4	888	-	44	56	-	58
	5	910	-	44	56	-	56
30	6	-	935	58	41	-	-
	7	-	874	56	41	-	43
	8	-	873	58	41	-	51
	9	-	880	56	41	41	-

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The refractive index of the uncured formulations were measured. The adhesion of the cured formulations to glass was measured by a drag test.

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The drag test consisted of coating the formulation to be tested on to a large glass slide. Lines were scored diagonally across the coating and a stylus to which a weight was attached was applied to the coating. The stylus was pulled across the coating. The weight applied to the stylus when a half of the lines are stripped away was recorded, in grams, as a measure of adhesion.

The refractive indices of the uncured, uncross-linked formulation at sodium D line wavelength and adhesion values are reported in the following Table 2.

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Table 2

Example	Adhesion	Refractive Index
50	2	240
	3	<160
	4	>800
	5	720
55	6	240
	7	400
	8	800
	9	160

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Examples 2 to 5 show the refractive index of the 3 component system was lower than the comparison formulation. Further that the glass adhesion of the 3 component system and adhesion enhanced systems was greater than that of the thiol silane containing formulation.

Coating using mono-acrylate B (Examples 6 to 9) were subjectively much more brittle than those using monoacrylate A.

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EXAMPLES 10 TO 13Comparison of the effect of fluorinated acrylate on adhesion

The formulations reported in Table 3 were prepared and refractive index and adhesion measurements were conducted as in Example 2.

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Table 3

Example	Mono-acrylate B	Mono-acrylate A	TMPTMA	IG651	Adhesion	Refractive Index	10
10	928	-	57	40	240	1.356	
11	-	927	54	44	640	1.392	
12	922	-	49	41	<160	not measured	15
13	-	946	51	44	720	not measured	

These results indicate that the fluoro-octyl sulphonamido acrylate monomers exhibit advantageous adhesion properties.

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EXAMPLES 14 TO 16

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Comparison of the effect of photoinitiator choice on adhesion

The formulations reported in Table 4 were used to coat glass slides. The adhesion properties of the formulations were measured as in Example 2.

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Table 4

Example	Mono-acrylate A	TMPTMA	acrylic silane	IG651	IG500	IG184	Adhesion	35
14	734	116	103	115	-	-	1040	
15	705	103	108	-	109	-	720	
16	701	126	114	-	-	100	800	

All of these commercial photoinitiators effected acceptable levels of cure.

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EXAMPLES 18 TO 23

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Comparison of the effect of cross-linking agent selection on adhesion

The formulation reported in Table 5 were used to coat glass slides. The adhesion of the formulations was measured as in Example 2.

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Table 5

Example	Mono-acrylate A	IG651	acrylic silane	TMPTMA	HHA	HDDA	Adhesion	
18	704	60	101	101	-	-	1040	55
19	696	61	103	50	-	-	1200	
20	715	60	105	-	114	-	(a)	
21	722	62	101	-	62	-	1200	
22	696	63	108	-	-	104	800	
23	702	61	100	-	-	51	720	60

(a) Very poor quality coatings led to inconsistent results

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EXAMPLE 245 Effect of acrylic silane concentration on adhesion

To a formulation comprising Mono-acrylate A, IG651 and TMPTMA in the weight ratio 92:4:4 was added the following proportion of acrylate silane. The adhesion to glass was measured as in Example 2.

	weight % acrylate silane	Adhesion
10	0	240
	1	200
	2.4	640
15	5	480
	6	640
	7.5	640
	11	800
	14	1040
	19	800
20	22.5	1040
	30	> 1040

25 It can be clearly seen that any amount of the acrylate silane over 10% was beneficial to core cladding adhesion.

EXAMPLES 25 TO 28

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Comparison with fibres of U.S. Patent No. 4511209

Optical fibres were prepared as in Example 1 using the following cladding compositions:

	Example	Mono-acrylate A	IG651	TMPTMA	acrylic acid	acrylate silane	thiol synergist
40	25	88	4	4	-	4	-
	26	88	4	4	4	-	-
	27	88	4	4	-	-	4
	28 ⁽¹⁾	72.1	0.9	23.3	-	-	3.7

(1) Table III, Example 14 of U.S. Patent 4511209
Comparative Attenuation at 820 nm

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	Example	Attenuation dB/Km
50	25	22
	26	11.9
	27	114
	28	48.4

55 The presence of the thiol synergist of the prior art does not lead to lower attenuation as in the cladding compositions of the invention.

Comparison of adhesion by lap shear test 0.5 inch (12.8 mm) overlap.

	Example	Immediately after cure	After 24 hrs	% Change
60	25	100.3	108.4	8.0
	26	123.7	178.2	44.0
	28	66.6	71.1	6.7

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Adhesion of cladding to silica of Examples 25 and 26 containing acrylic acid or acrylate silane is considerably improved over the cladding of Example 28 containing thiol synergist. The improvement is particularly pronounced upon ageing.

Example 29

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Addition of thermal stabilizer

Optical fibres were prepared as in Example 1 using a cladding composition of the following formulation: 10

%		by weight
mono-acrylate A	88.5	
TMPTA	5	
acrylate silane	2	15
IG651	4	
Ultranox 226	0.5	

After thermal cycling at +125°C the fibre exhibited a permanent loss damage of 7 dB/Km compared to 10 to 14 dB/Km of fibres having the same cladding formulation without Ultranox 226 thermal stabilizer. 20

Example 30

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Combination of two thermal stabilizers

An optical fibre was prepared as in Example 1 using the following cladding formulation.

%		by weight
mono-acrylate A	82.25	
TMPTA	10	
acrylate silane	5	
Darocur 1116	2	
Cyanox LTDP	0.5	35
Irganox 1076	0.25	

After curing the clad fibre was extrusion coated with Tefzel 210 in a conventional manner. The permanent loss damage of the resulting buffered optical fibre was 1.1 Km/dB after being annealed at +125°C for four hours. 40

Example 31

A cladding composition was prepared by mixing the following components:

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1,1-dihydroperfluorocyclohexane carbinol	88 parts by weight
acrylate	
2-ethyl-2-(hydroxy-methyl)-1,3-propandiol triacrylate	5 parts by weight
3-(trimethoxysilyl)propyl methacrylate	5 parts by weight
Darocur 1173	2 parts by weight

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Coated fibres were prepared and evaluated using the procedure according to Example 1. An attenuation figure of 5.73 dB/Km at 820 nm was recorded. After curing the cladded fibre was extrusion coated with Tefzel 210 in a conventional manner to provide a buffered optical fibre with an attenuation loss of 6.23 dB/Km at 820 nm. The thermal stability of the Tefzel buffered fibre was evaluated after maintaining it at 125°C for four hours and was recorded as 10.58 dB/Km. 60

The 1,1-dihydroperfluorocyclohexane carbinol acrylate used in this Example was prepared according to the procedure disclosed by D.W. Codding et al., "Journal of Polymer Science", 15, 518 (1955) except that the charge was 210 g trifluoroacetic anhydride, 79.8 g acrylic acid, 250 g perfluorocyclohexylmethanol, and 0.1 g

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phenathiazine as inhibitor; the reaction mixture was stirred for 2 hours after the reaction had subsided, and the product was purified by vacuum distillation.

5 A comparison was made of the Tefzel coated cladded fibre prepared in this Example with a commercially available hard clad silica fibre sold by Ensign-Bickford (Simsbury, CT). Both fibres were maintained at 125°C for four hours. The instant fibre was colorless and transparent and showed no increase in attenuation at 600 nm whereas the Ensign-Bickford fibre yellowed and showed an increase in attenuation of 120 dB/Km at 600 nm. "Transparent" means that the cladded fibre when viewed under an optical microscope (e.g., at 100X), have the property of transmitting rays of visible light so that bodies beneath the fibre, for example, such as bodies having essentially the same nature as the fibre, can be clearly seen through the fibre.

10 Improved properties of the cladded fibre can be realized by including antioxidant/thermal stabilizer in the formulation as has been shown in Example 30.

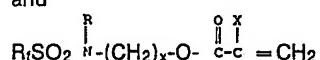
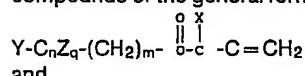
Claims

15 1. An optical fibre comprising a core coated with a cladding having a lower refractive index than the core, the cladding composition comprising a fluorinated monoacrylate, a polyfunctional cross-linking acrylate being difunctional or higher, and a photoinitiator, the composition comprising less than 0.3% by weight of a mono- or polyfunctional thiol and being cured or crosslinked.

20 2. An optical fibre as claimed in Claim 1 in which the cladding composition is free from mono- or polyfunctional thiol.

3. An optical fibre as claimed in any preceding claim in which the fluorinated mono-acrylate comprises a fluoroaliphatic radical or a fluorinated cycloaliphatic radical in which the higher of a minimum of three C-F bonds are present or 25% of the C-H bonds have been replaced by C-F bonds.

25 4. An optical fibre as claimed in any preceding claim in which the fluorinated acrylate is selected from compounds of the general formulae:



in which:

Y represents H, F or Cl;

X represents H or an alkyl group of 1 to 5 carbon atoms,

n is an integer from 2 to 12,

q is an integer from 4 to 24,

m is 0, 1 or 2,

with the proviso that for Z not more than one atom of H or Cl is present for every two carbon atoms in the group C_nZ_q ,

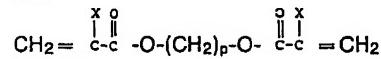
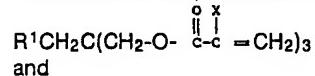
40 R represents an alkyl group of 1 to 5 carbon atoms,

R_1 represents a fluoroaliphatic radical as defined in Claim 3 and,

x is 1 or 2.

45 5. An optical fibre as claimed in Claim 4 characterised in that the fluorinated acrylate is selected from 1,1-dihydroperfluorocyclohexane carbinol acrylate, 1,1-dihydroperfluorocyclohexane carbinol methacrylate, 1,1-dihydroperfluorocyclopentane carbinol acrylate, 1,1-dihydroperfluorocyclopentane carbinol methacrylate, 1,1-dihydroperfluoro-octyl acrylate, 1,1-dihydroperfluoro-octyl methacrylate, 1,1-dihydroperfluoro-butyl acrylate, 1H,1H,5H-octafluoro-pentyl acrylate, 1H,1H,11H-eicosfluoro-undecyl acrylate, hexa-fluoro-isopropyl acrylate, 2-(N-ethyl perfluoro octane sulphonamido)ethyl acrylate, 2-(N-ethyl perfluoro octane sulphonamido)ethyl methacrylate, 2-(N-butyl perfluoro octane sulphonamido)ethyl acrylate and mixtures thereof.

50 6. An optical fibre as claimed in any preceding claim characterised in that the cross-linking acrylate is selected from compounds of the general formulae:



in which:

X is as defined in Claim 4,

60 R^1 represents an alkyl group of 1 to 5 carbon atoms or $-O-CO(X)-CH_2$ in which X is as defined above, and p is an integer from 3 to 8.

65 7. An optical fibre as claimed in any preceding claim characterised in that the cross-linking acrylate is selected from trimethylol propane tri(meth)acrylate, 1,4 butanediol di(meth)acrylate, 1,3 butanediol di(meth)acrylate, 1,6 hexanediol di(meth)acrylate, pentaerythritol tetra(meth)acrylate, pentaerythritol tri(meth)acrylate, dipentaerythritol penta(meth)acrylate, and hydantoin hexa acrylate and mixtures

thereof.

8. An optical fibre as claimed in any preceding claim in which the cladding composition comprises:

fluorinated mono-acrylate	50 to 95% by weight
polyfunctional cross-linking acrylate	2 to 35% by weight
photoinitiator	0.5 to 20% by weight.

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9. An optical fibre as claimed in Claim 8 in which the cladding composition comprises:

fluorinated mono-acrylate	75 to 95% by weight
polyfunctional cross-linking acrylate	2 to 35% by weight
photoinitiator	0.5 to 10% by weight.

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10. An optical fibre as claimed in any preceding claim in which the cladding composition additionally comprises from 1 to 50 % by weight of the total cladding composition of an adhesion enhancer having a vinyl functionality different from the fluorinated mono-acrylate and the cross-linkable acrylate.

11. An optical fibre as claimed in Claim 10 in which the adhesion enhancer is a (meth)acrylic silane.

12. An optical fibre as claimed in any preceding claim in which the cladding composition additionally comprises from 0.001 to 5% by weight of the total cladding composition of a thermal stabilizer/antioxidant.

13. An optical fibre as claimed in Claim 12 in which the thermal stabilizers/antioxidant is selected from 2,6-di-tert-butyl-4-methyl phenyl, octadecyl-3,5-di-tert-butyl-4-hydroxyhydrocinnamate, 2,6-di-tert-butyl-4-sec-butyl phenol, dilauryl thioldipropionate and combinations thereof.

14. An optical fibre as claimed in any preceding claim in which the core is fused silica the refractive index of the cladding is at least 0.03 units less than that of the core.

15. A cladding composition for optical fibres comprising from 50 to 95% by weight of a fluorinated acrylate, from 2 to 35% by weight of a polyfunctional cross-linking acrylate being difunctional or higher and from 0.5 to 20% by weight of a photoinitiator, the composition comprising less than 0.3% by weight of a mono- or polyfunctional thiol.

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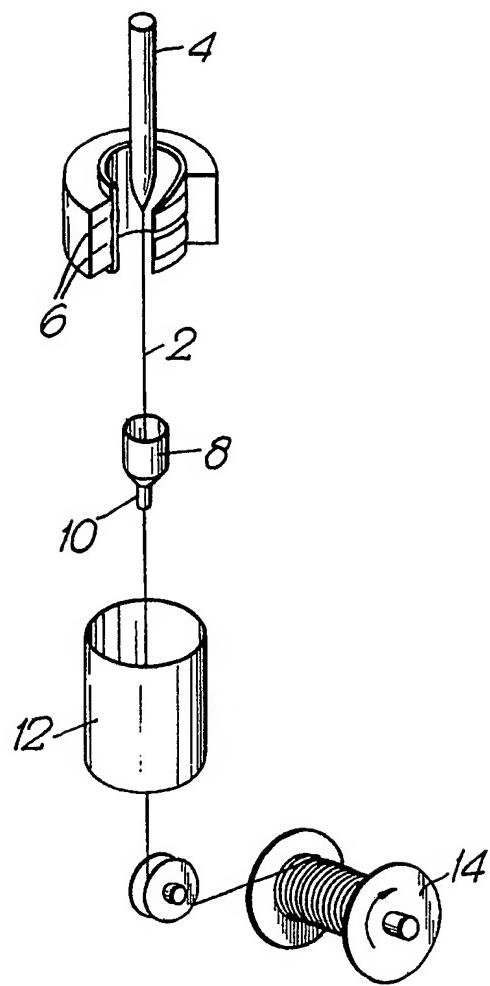
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Fig.1.





EP 89 30 2568

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	EP-A-0 257 863 (MITSUBISHI RAYON CO., LTD) * Claims 1-9 * ---	1-15	C 03 C 25/02 C 03 C 13/04 B 29 D 11/00
X	EP-A-0 256 765 (MITSUBISHI RAYON CO., LTD) * Claims * ---	1-13, 15	
X, D	US-A-4 511 209 (B.J. SKUTNIK) * Claim 1 * ---	1-15	
A	EP-A-0 250 996 (DAIKIN INDUSTRIES) * Claims * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. CL4)
			C 03 C
<p>The present search report has been drawn up for all claims</p>			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	20-06-1989	BOURUCHE J.P.E.	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			